CME Initiation & Propagation

- Modeling the Inputs of CMEs to the Magnetosphere
- Modeling self-consistent CME intitiation

- *Chip Manchester*

Outline

Simulation of CME initiation

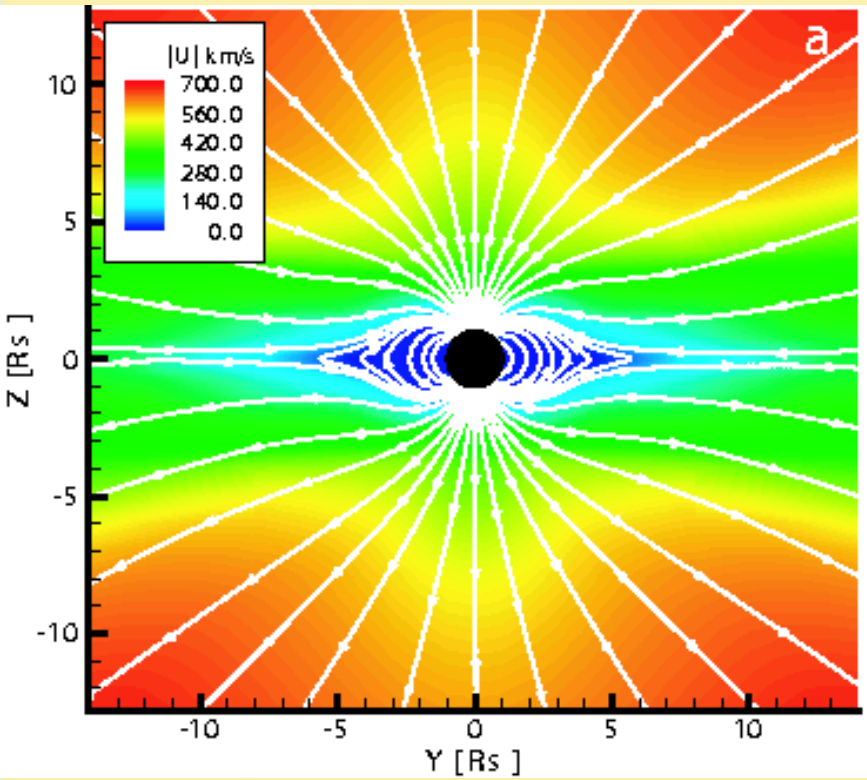
- Gibson-Low Flux Rope Model: Generic Event

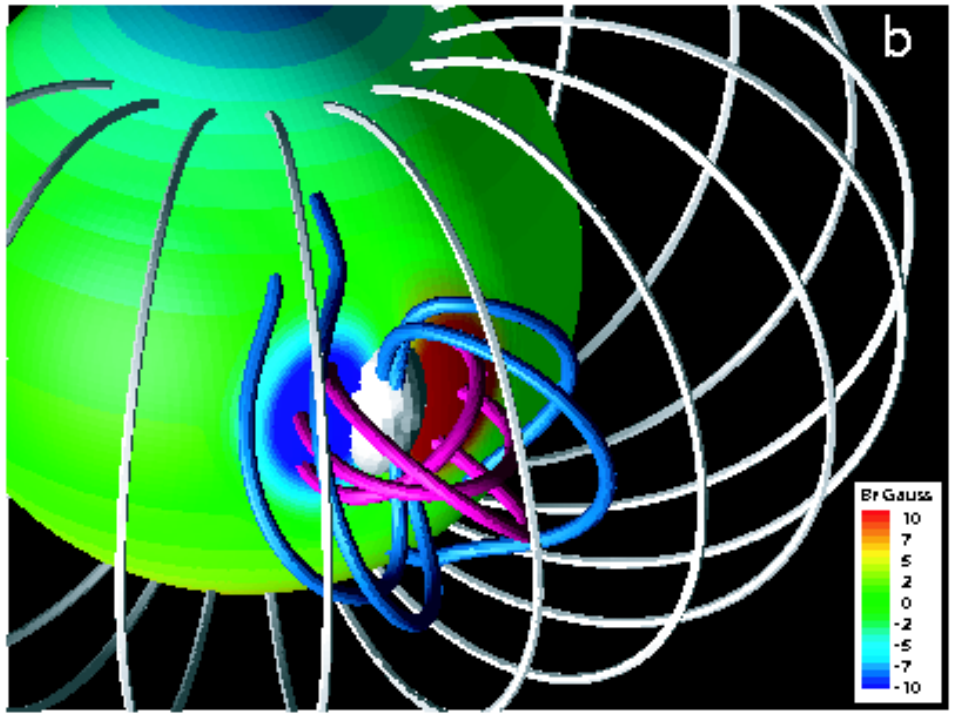
Recent Progress: CME events with the AWSoM model

- 2011 March 7th Event
- 2005 May 13th Event

Flux Emergence Model for Energy Buildup & CME Initiation

Initial State: Solar Wind and Gibson-Low Flux-Rope Driven CME

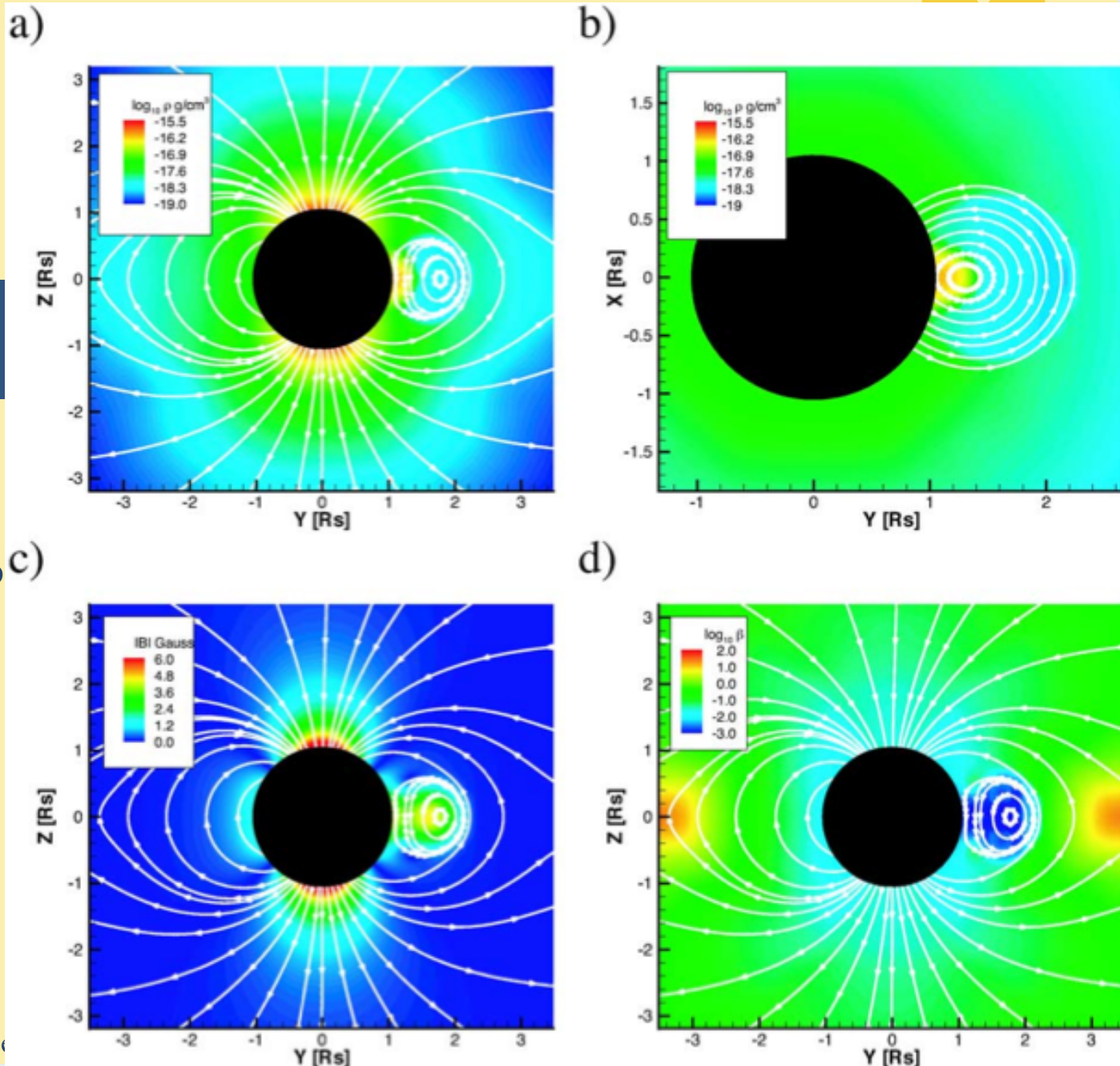




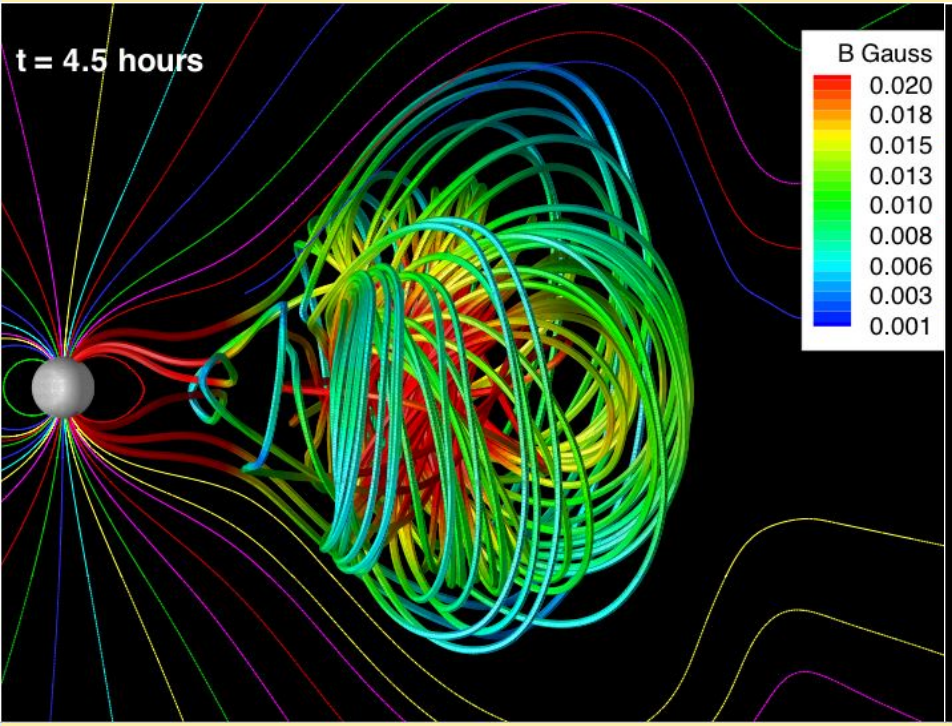
3D flux rope model of Gibson-Low 1998

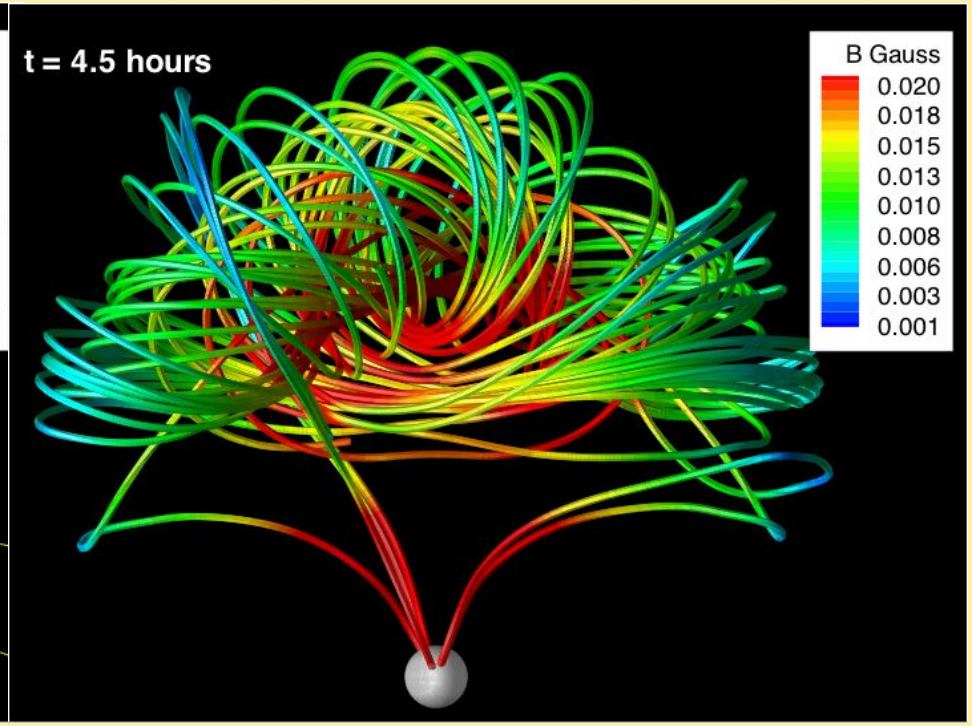
GL Flux rope CME Model

Manchester et al. 2004 a,b
Lugaz & Manchester 2005a,b
Manchester et al. 2005
Manchester et al. 2006 a,b
Lugaz et al 2007 a,b

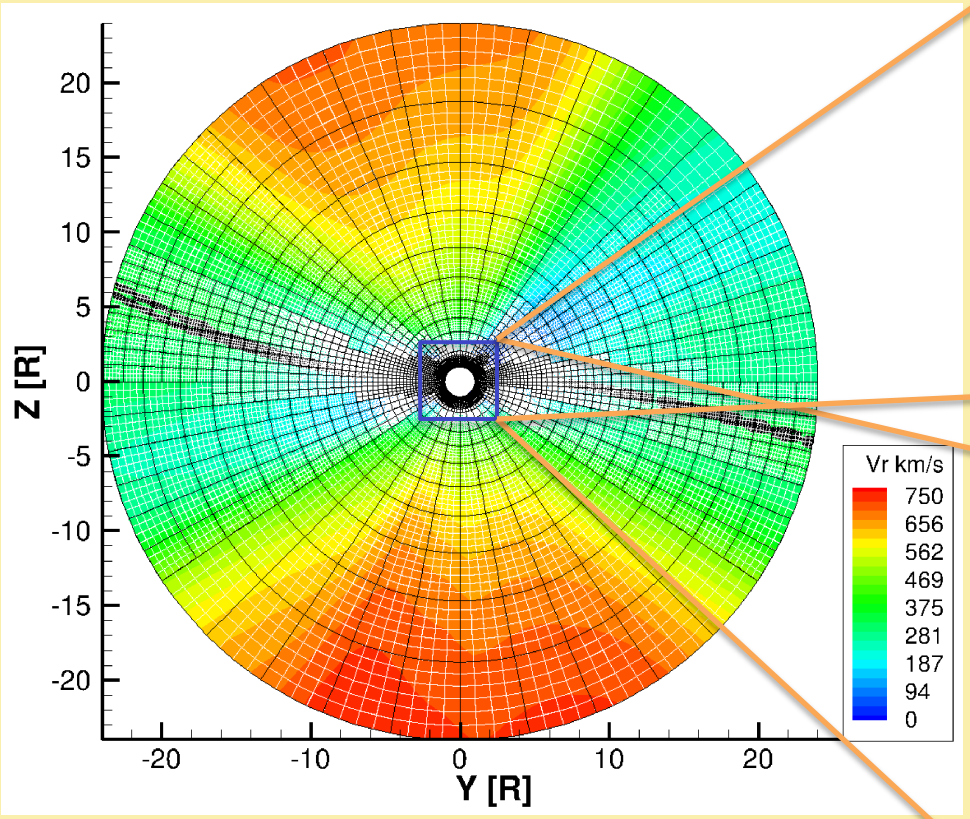


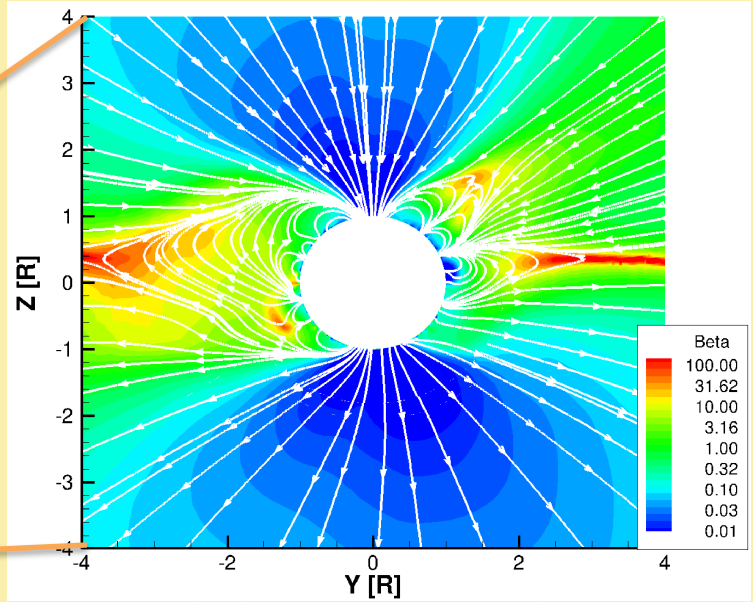
3D GL Flux Rope Structure

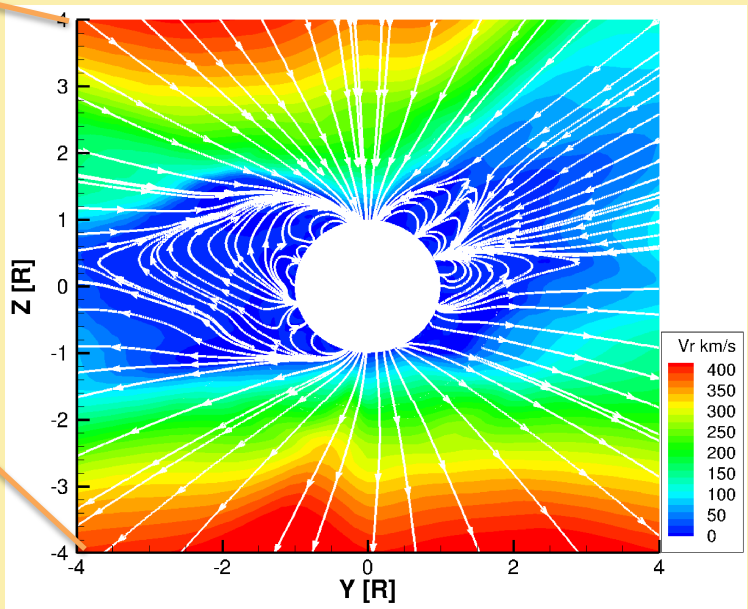




Solution for CR2107 (Feb-Mar 2011)



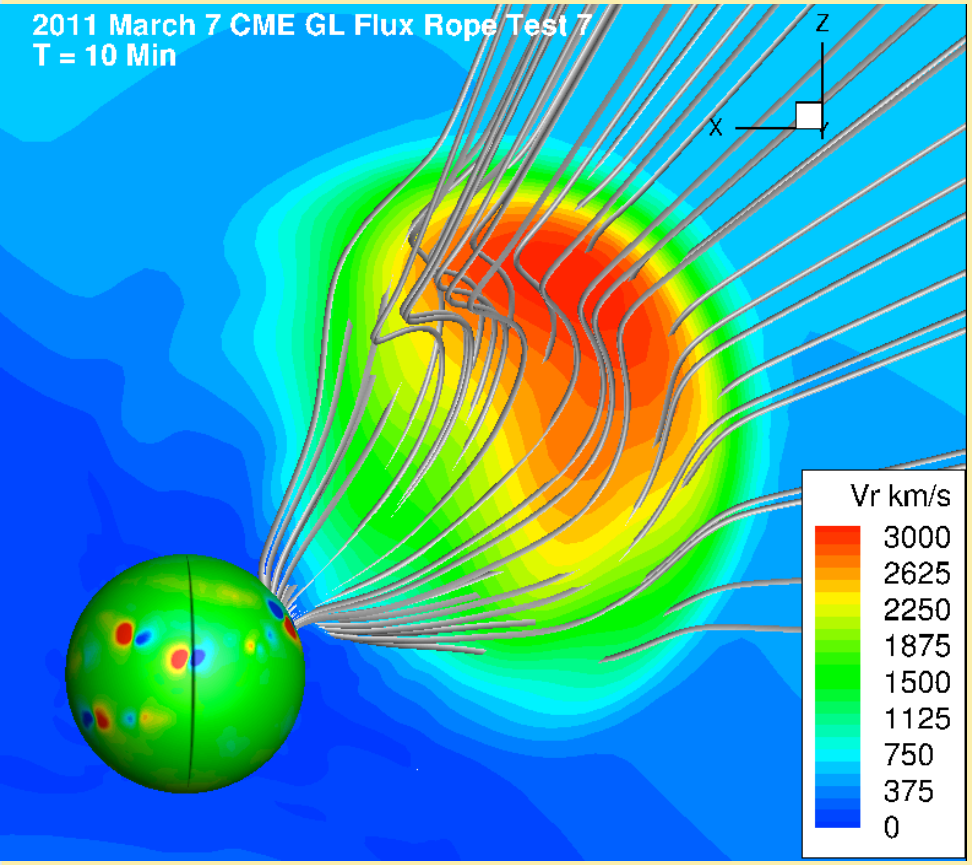


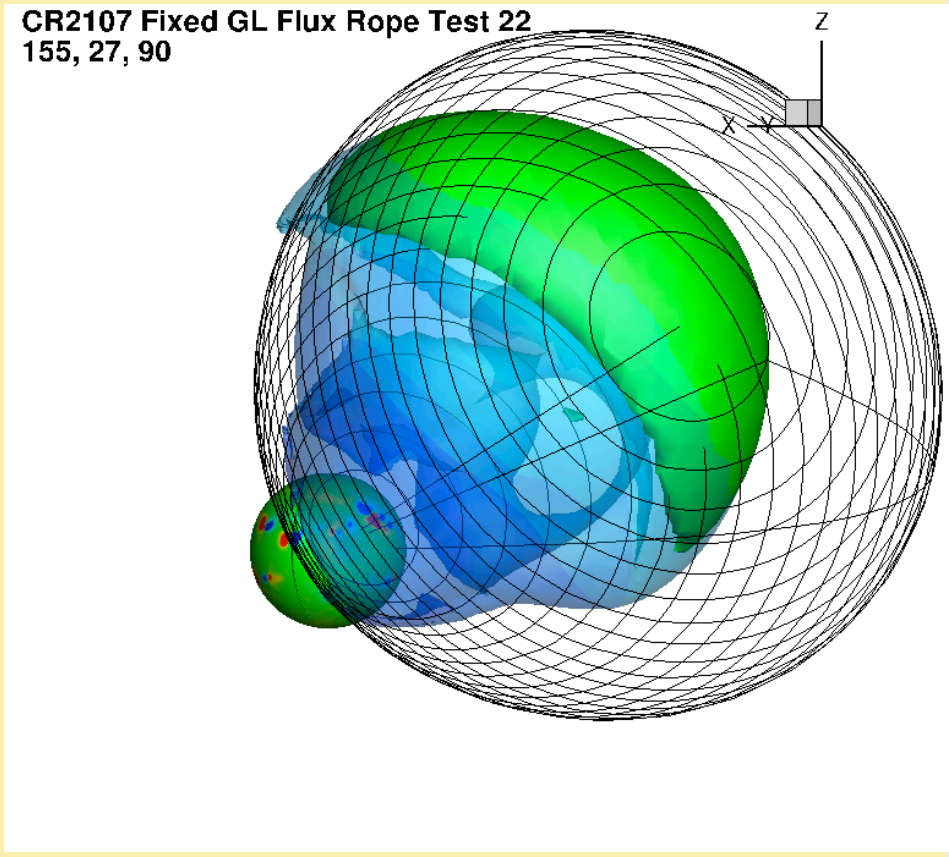


Meng Jin et al. in preparation

Modeling the 2011 March 2011 CME Event

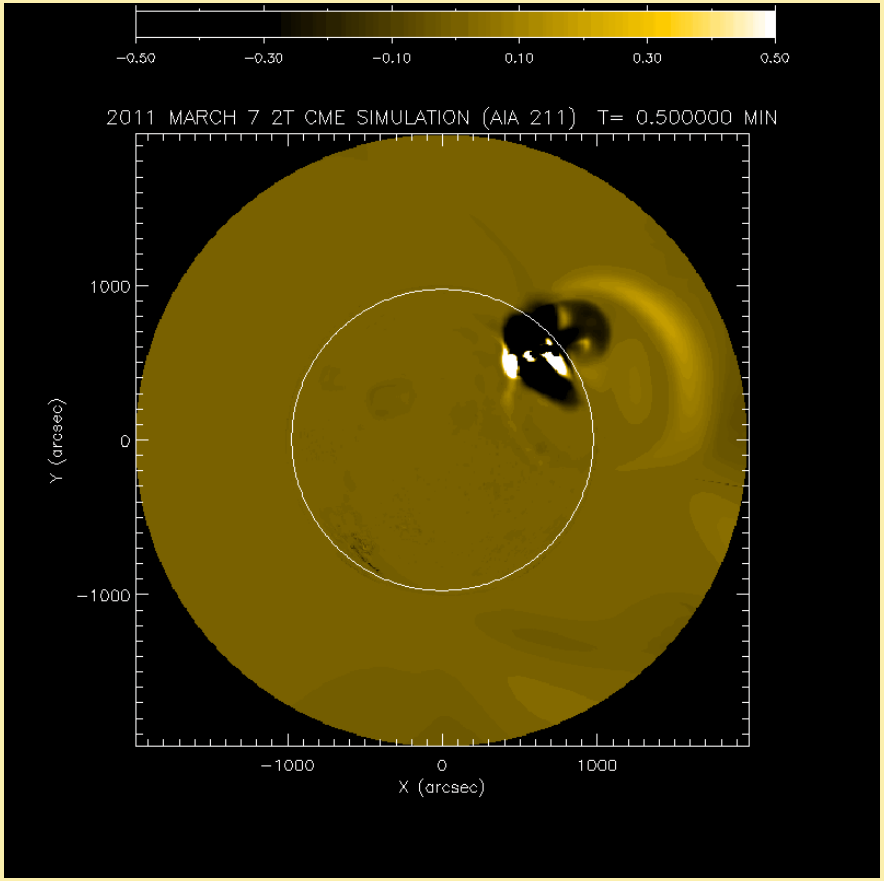
- Position rope to match cone model position (Kurt de Koning)



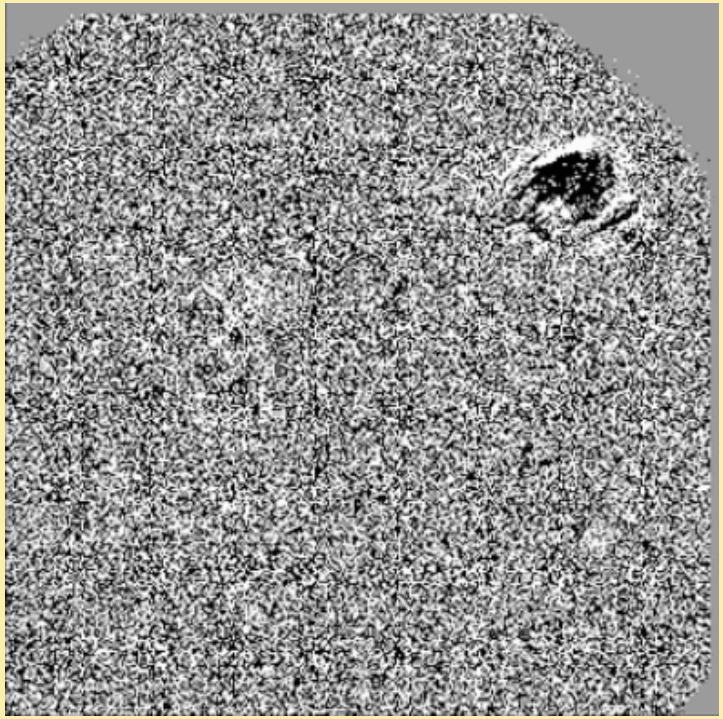


Simulated AIA waves

Simulated AIA 211

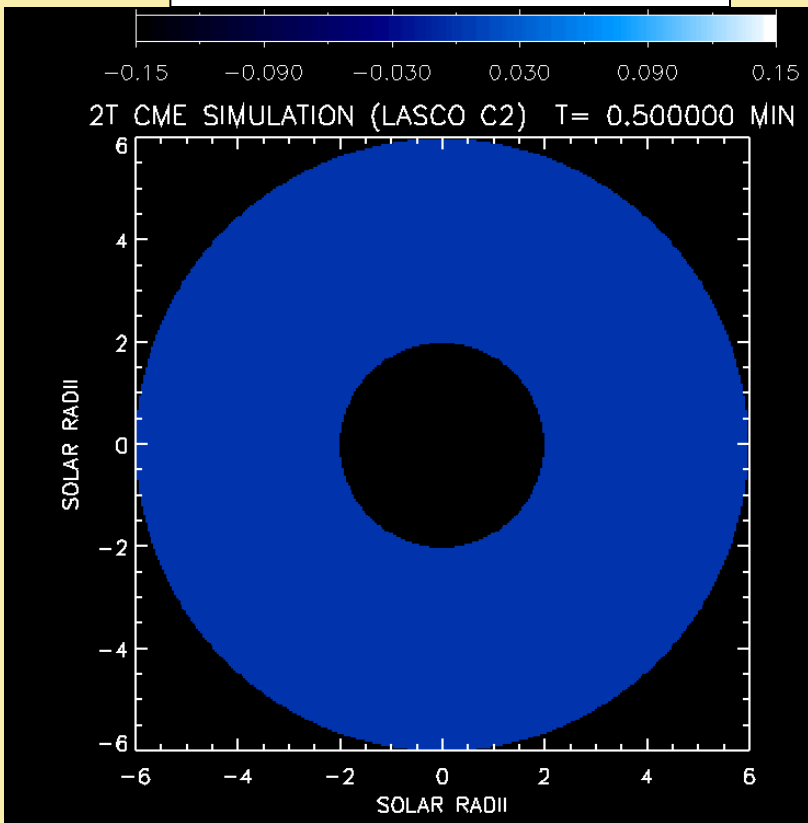


Observed AIA 211

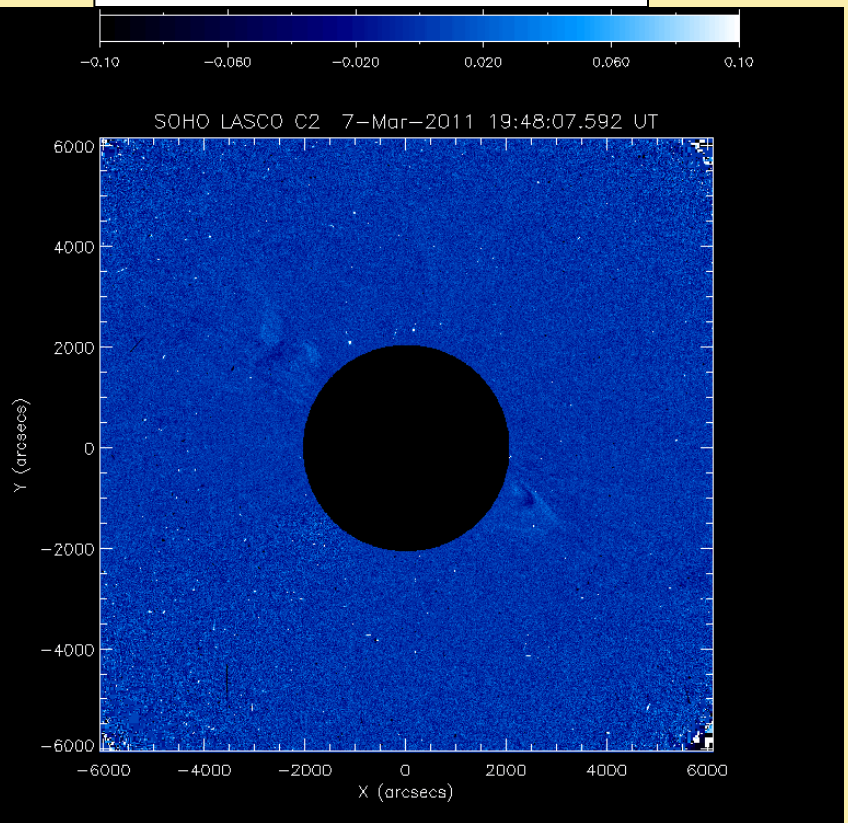


Simulated White Light Images

Simulated LASCO C2



Observed LASCO C2



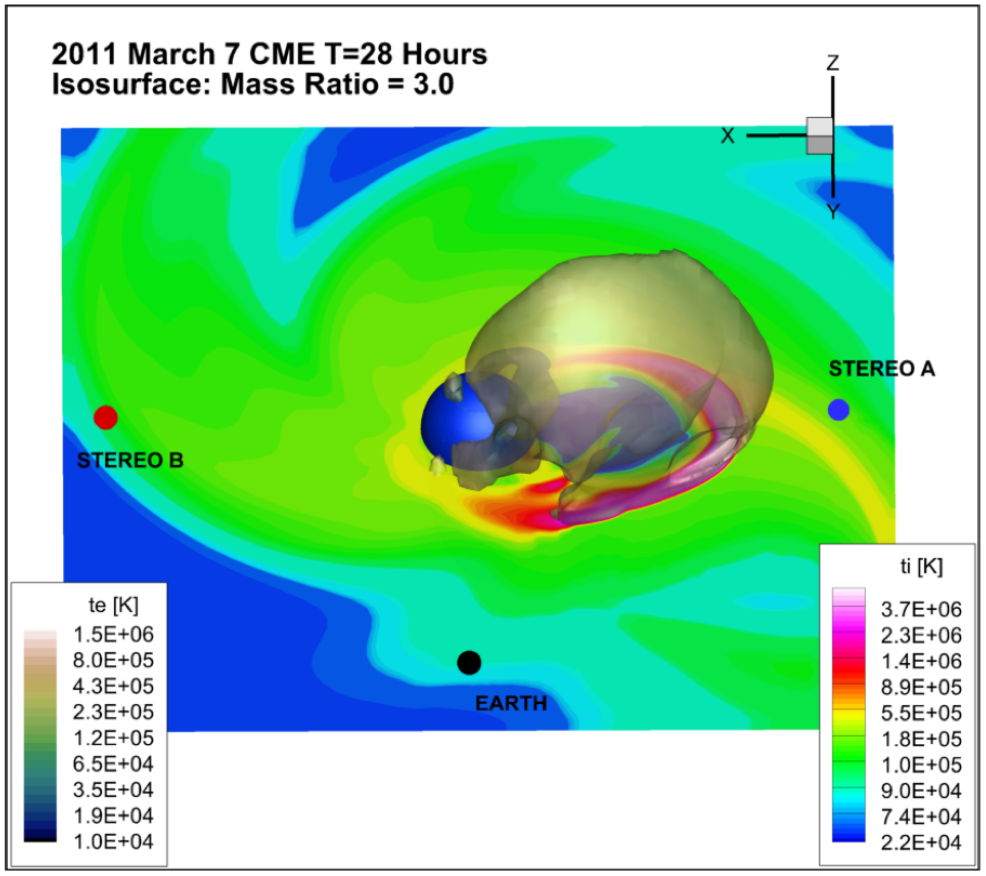
- Typical double front morphology (Voulidas & Ontiveros, 2009) in which faint front is caused by shock and bright front is coronal plasma piled up at the top of the erupting flux rope

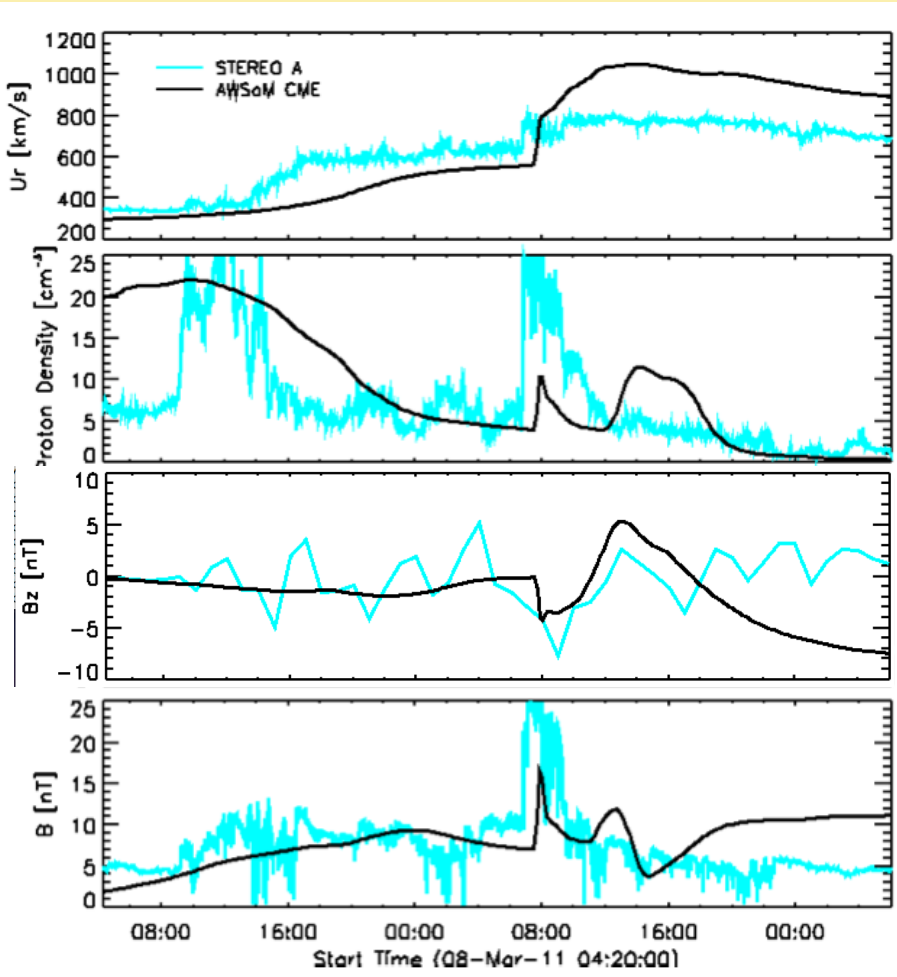
March 7th 2011 CME Simulation

CME Simulation with the AWSoM Model:

- Gibson-Low flux rope erupts from active region 11164
- The simulation matches the arrival time with 1 hour
- Predicts Bz direction correctly at the CME and the magnitude is within a factor of 2

Meng Jin et al. in preparation



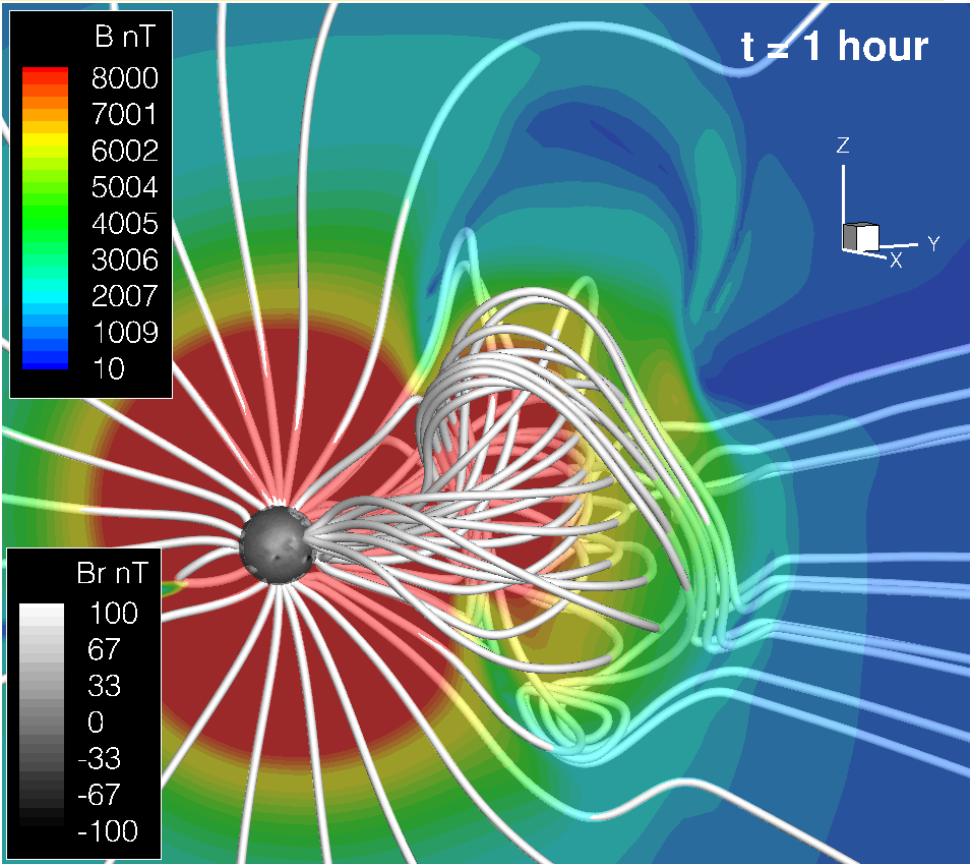


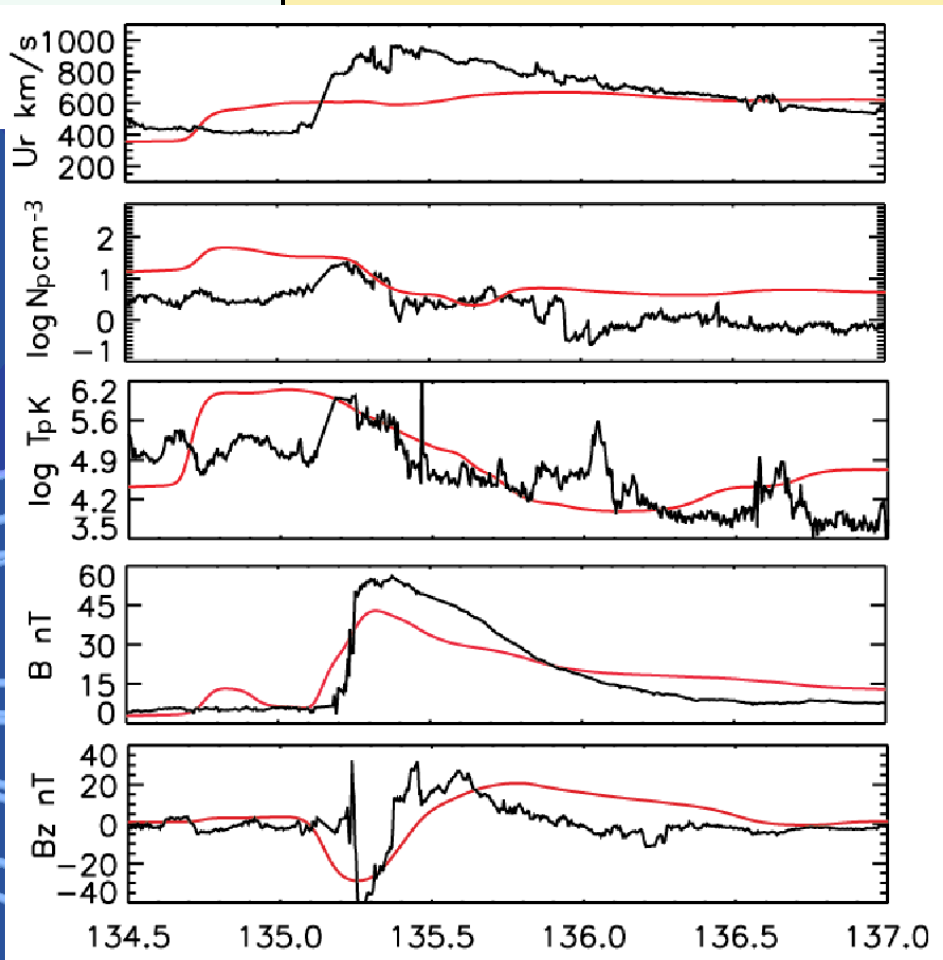
May 13th 2005 CME Simulation

CME Simulation with the AWSoM Model:

- Gibson-Low flux rope erupts from active region 10759
- The simulation reproduces the magnetic cloud signatures at 1 AU including the Bz rotation.

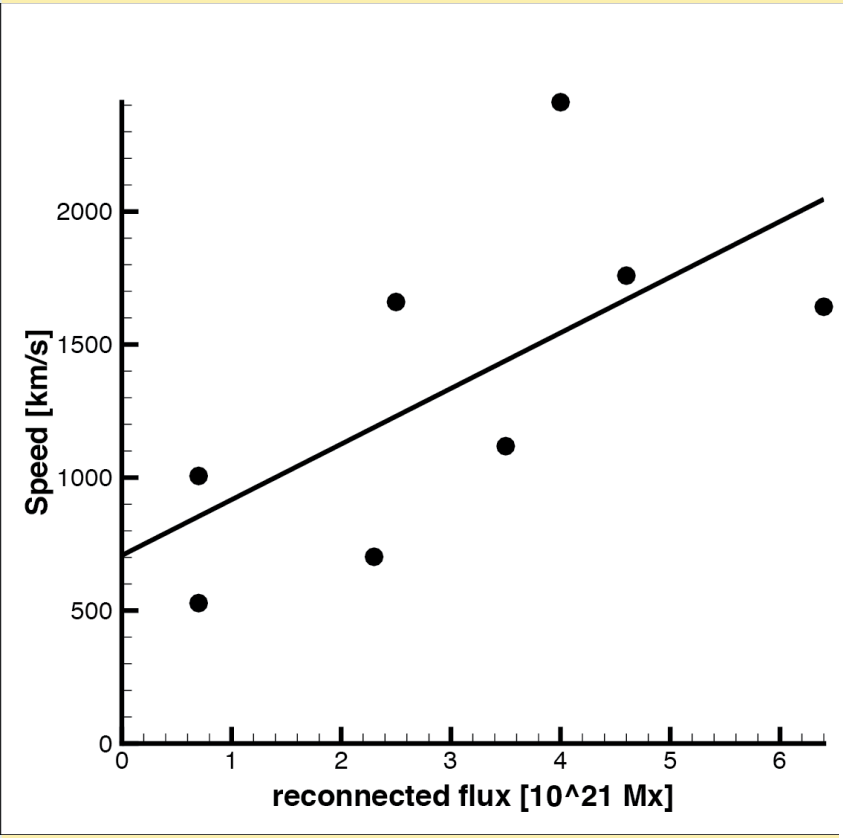
Manchester, van der Holst & Lavraud, Plasma Phys. Contol. Fusion, 56, 2014 .



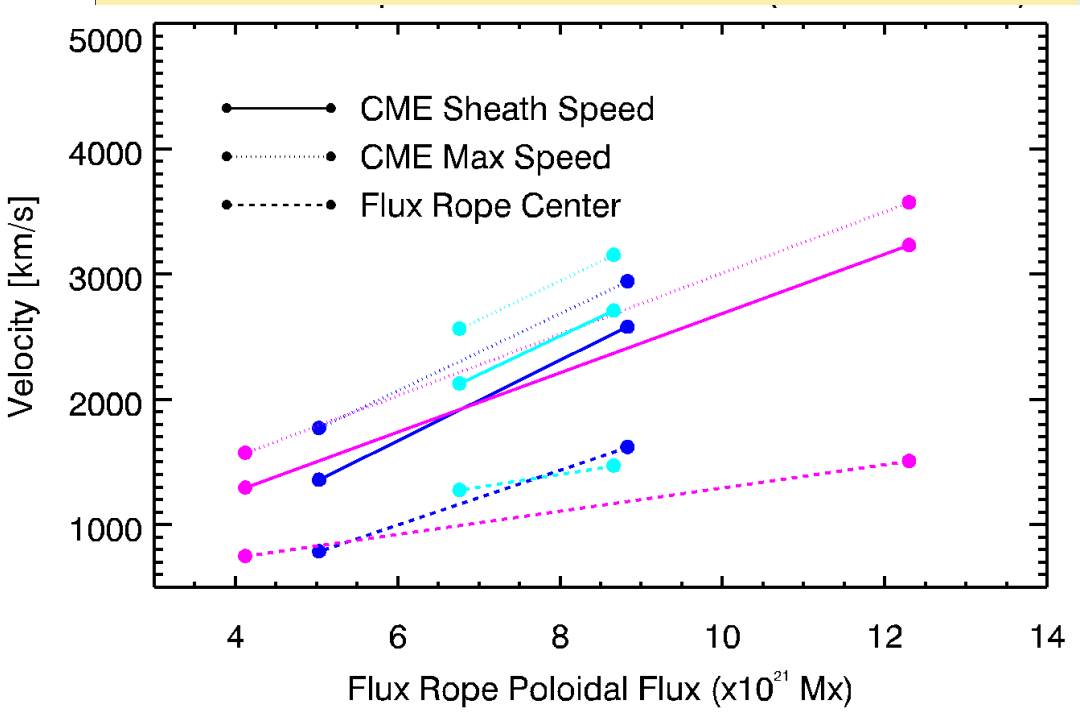


CME-Speed flux relationship

Left: Qiu et al. 2007

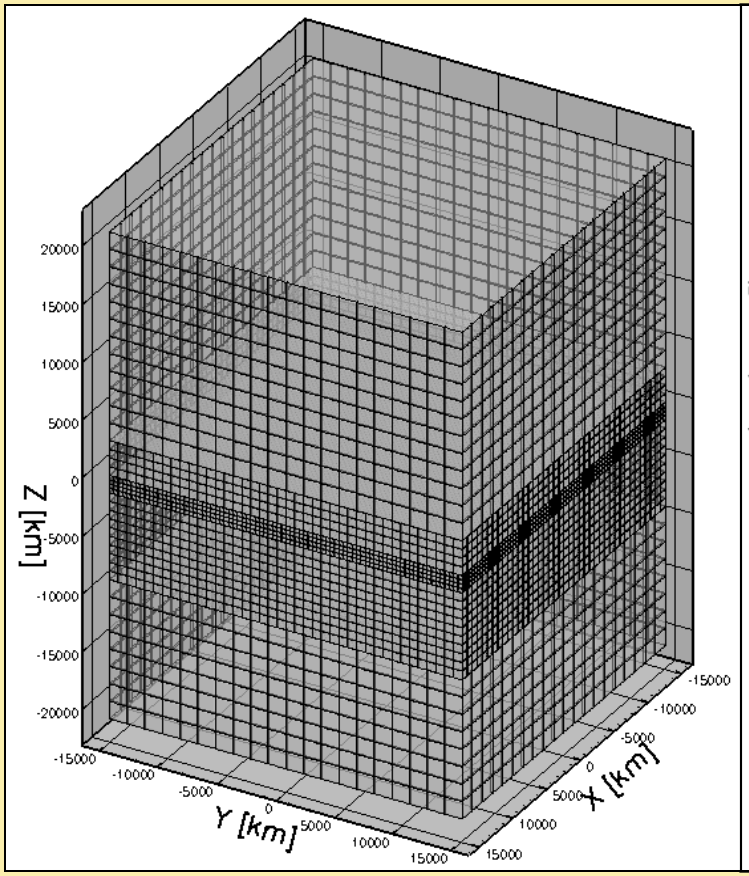


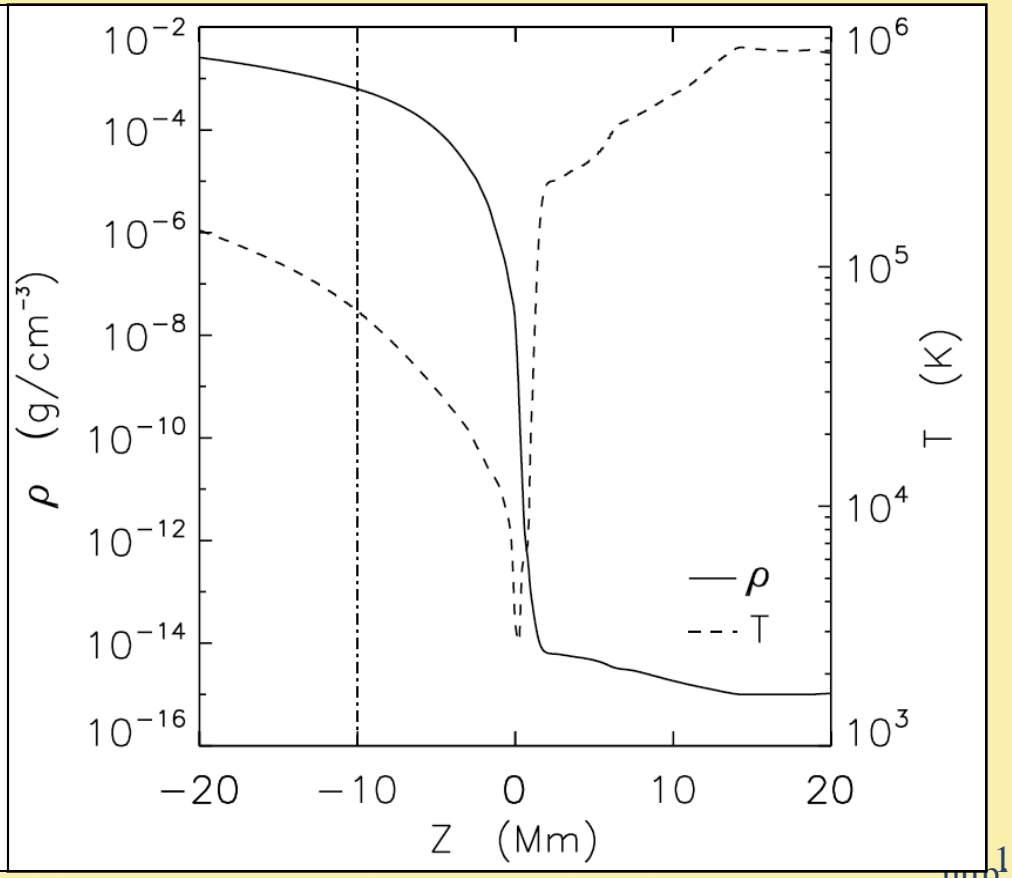
Right: GL flux rope results



Magnetic Flux Emergence

- Radiative Losses (Abbett 2007)
- Tabular Equation of State (Rogers 2000)
- Simulation domain: 30×30×42 Mm^3 (photosphere at center)
- Δx ranges from 0.25 to 1 scale height
- Fang, Manchester Abbett & van der Holst 2010, 2012, 2012





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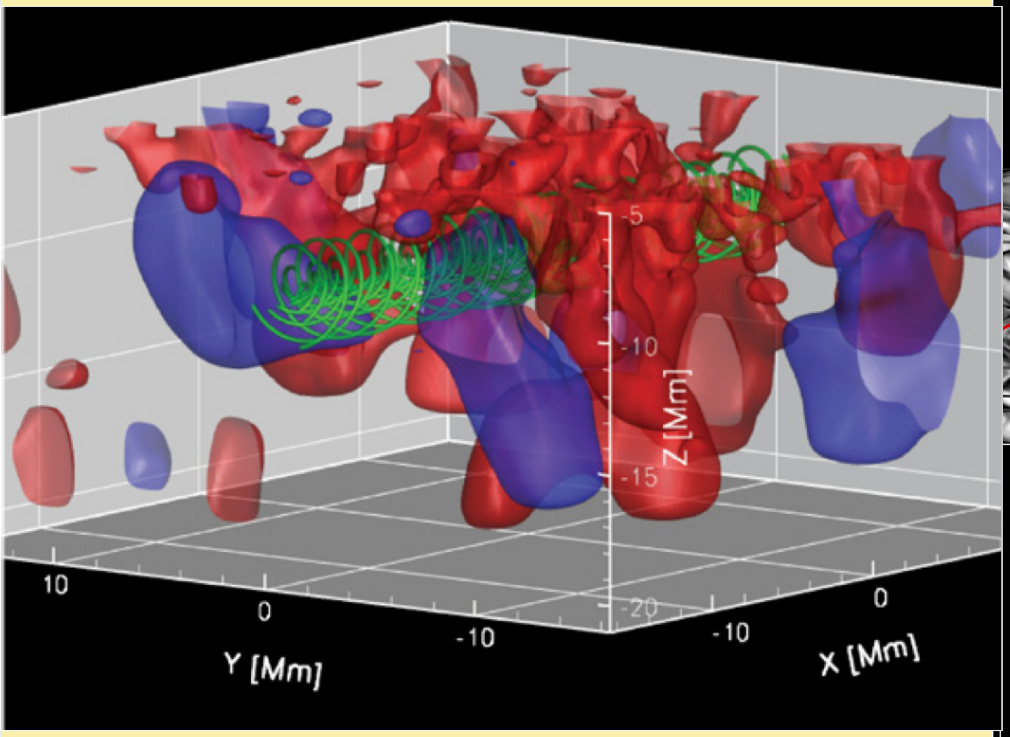
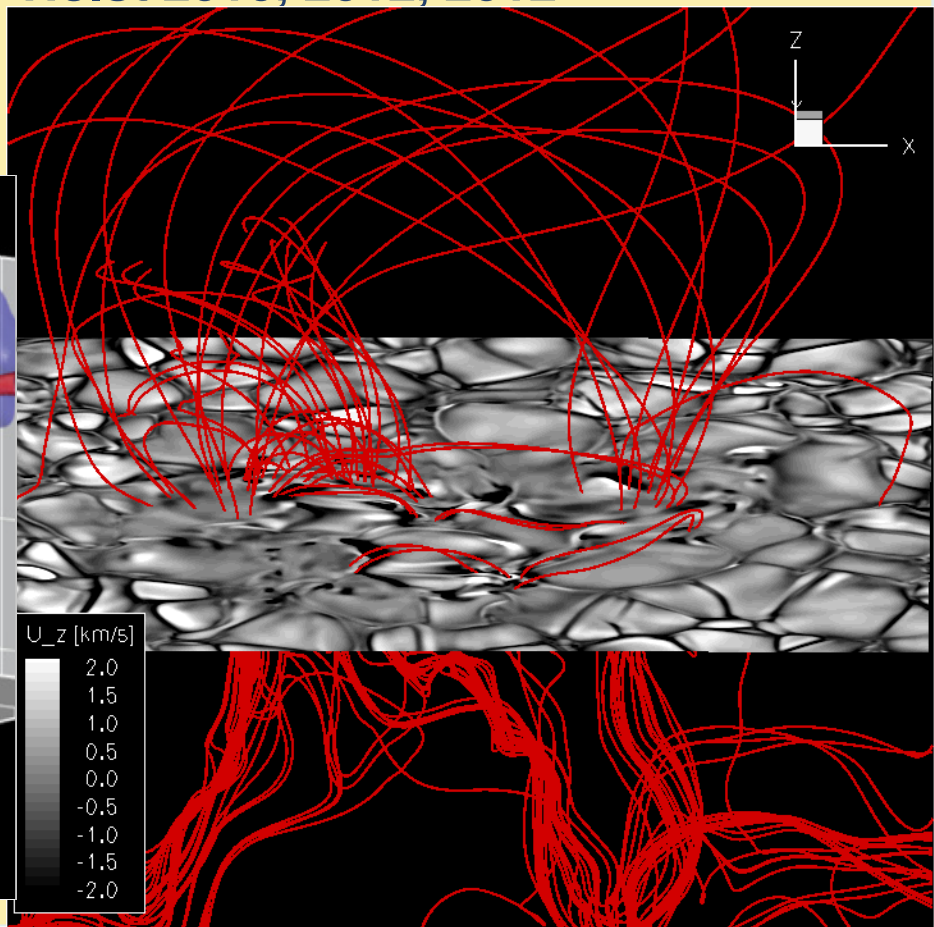
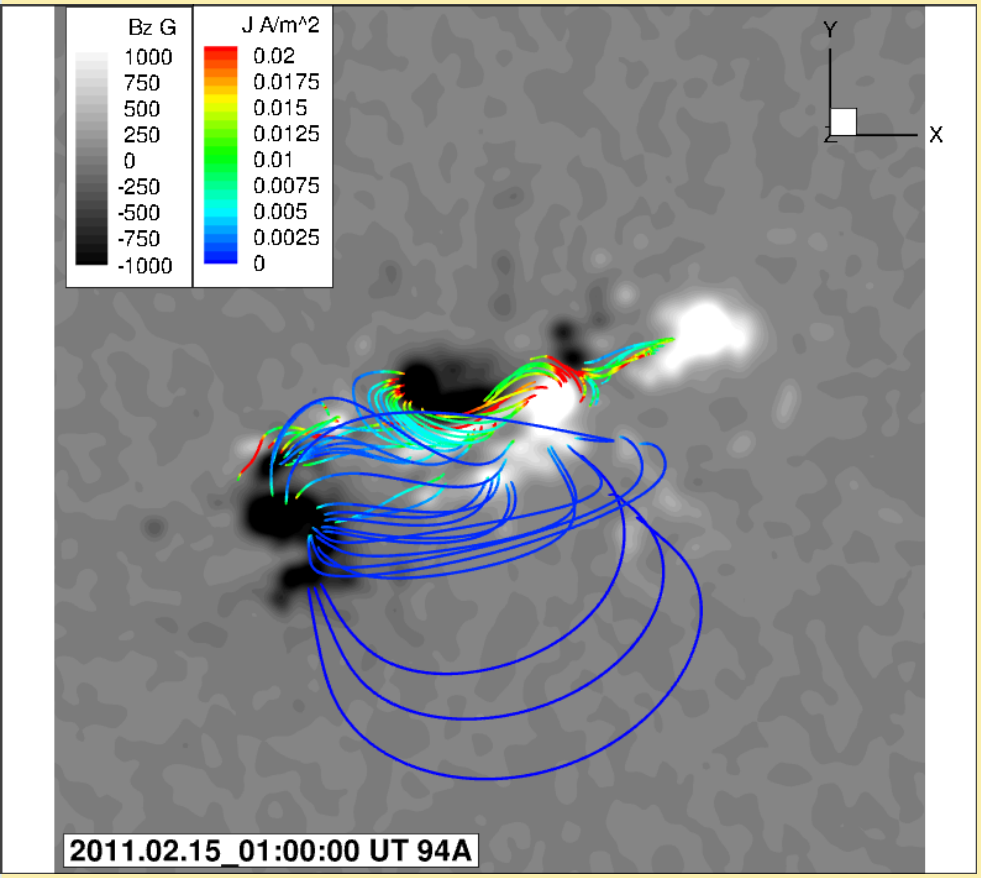
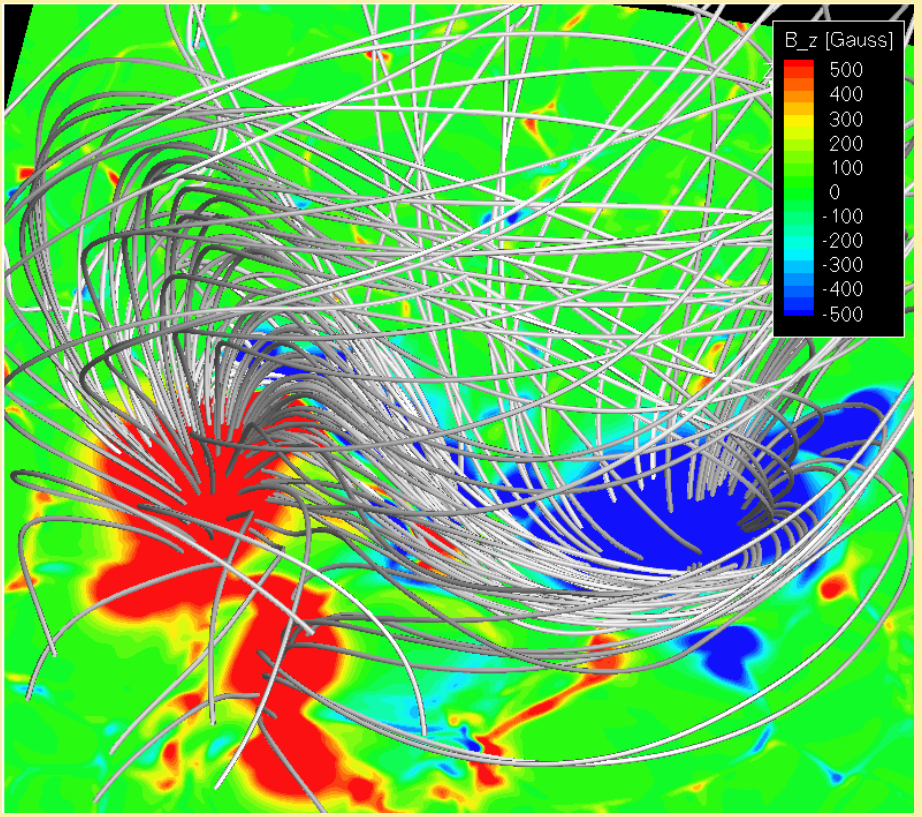




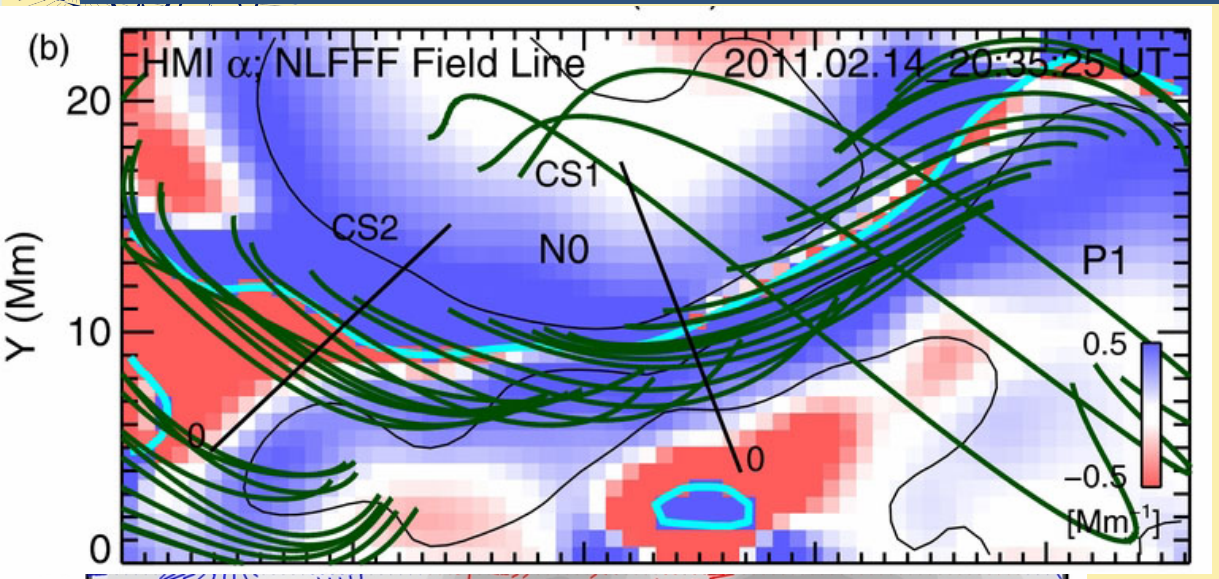
Shear in Coronal Field Lines

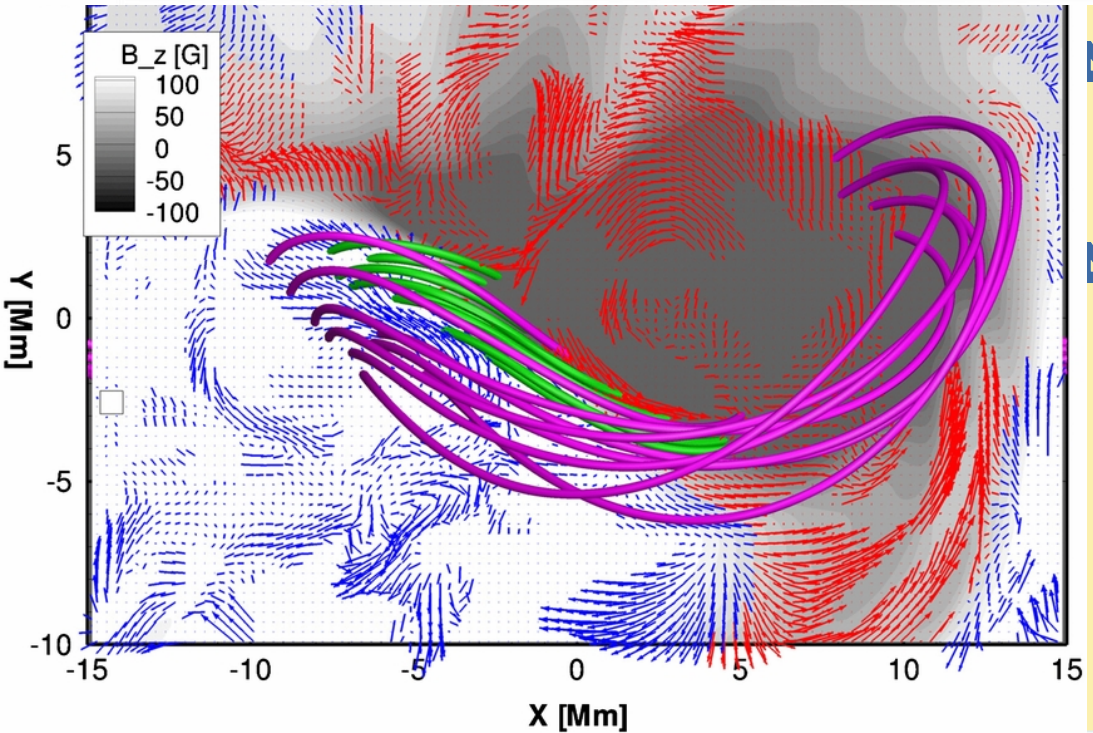




Y. Sun et al. 2012 (AR11158) F. Fang et al. 2012

Shear Coronal Field Lines

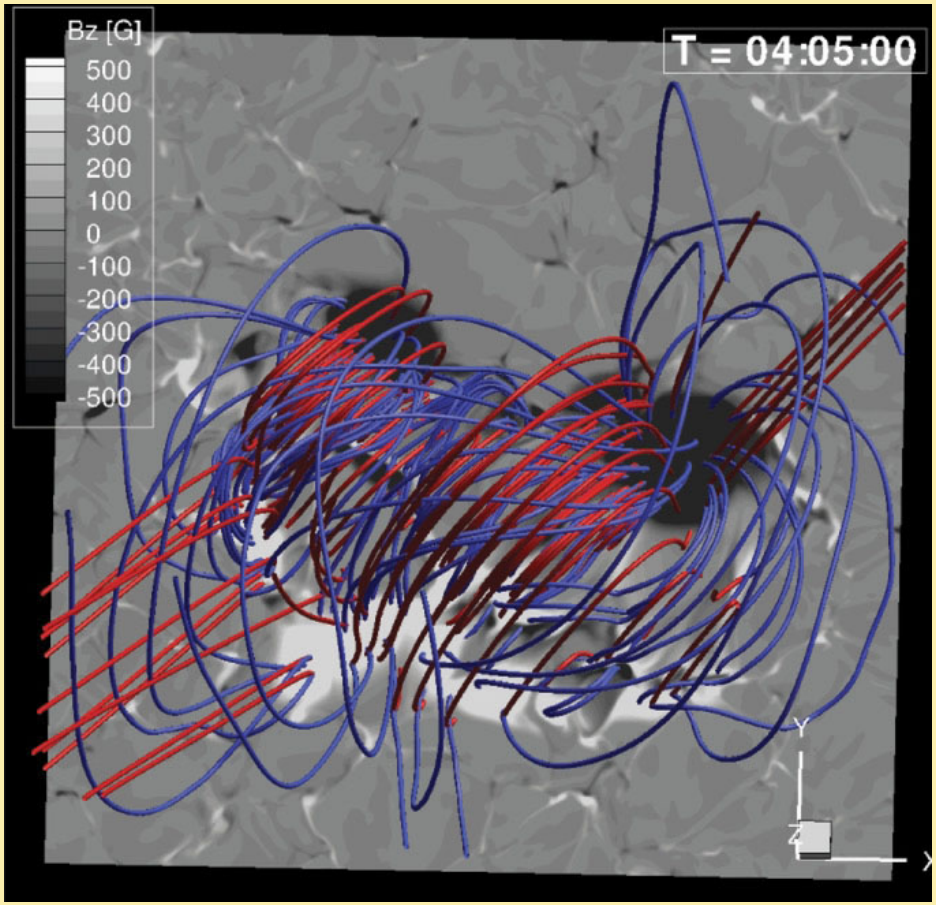


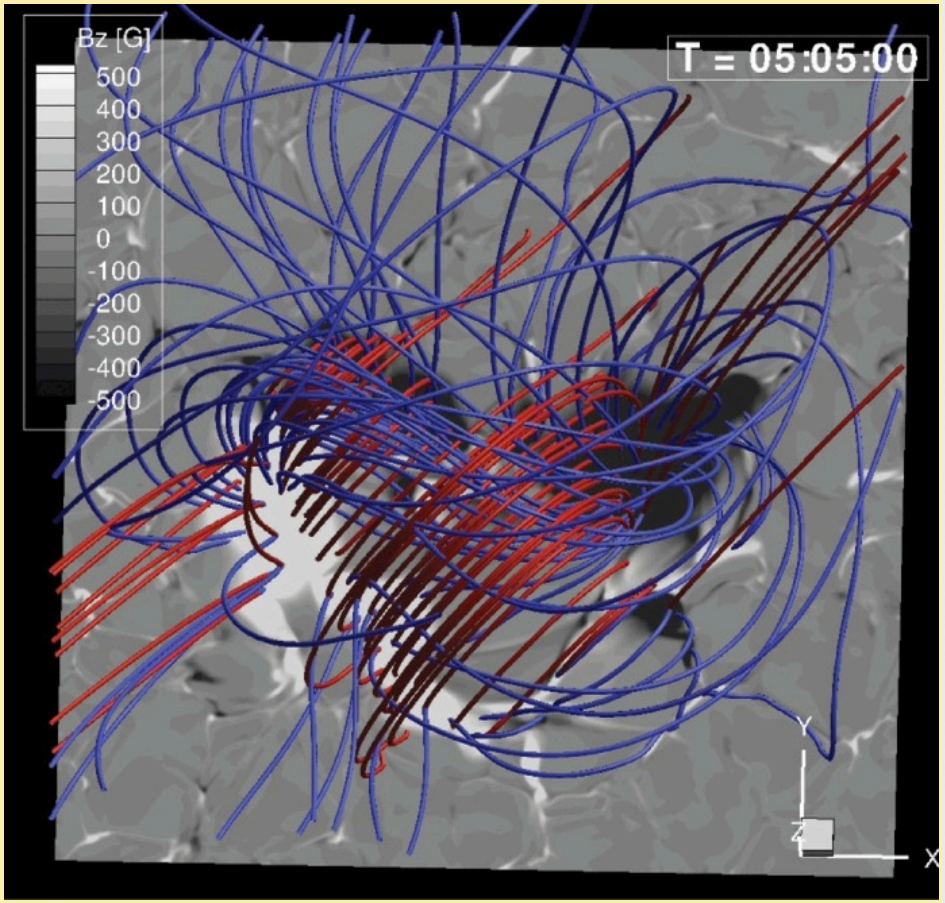


- Sun et al. 2012: NLFFF for AR 11158
- Fang et al. 2012

Coronal B Lines: Simulation + Potential

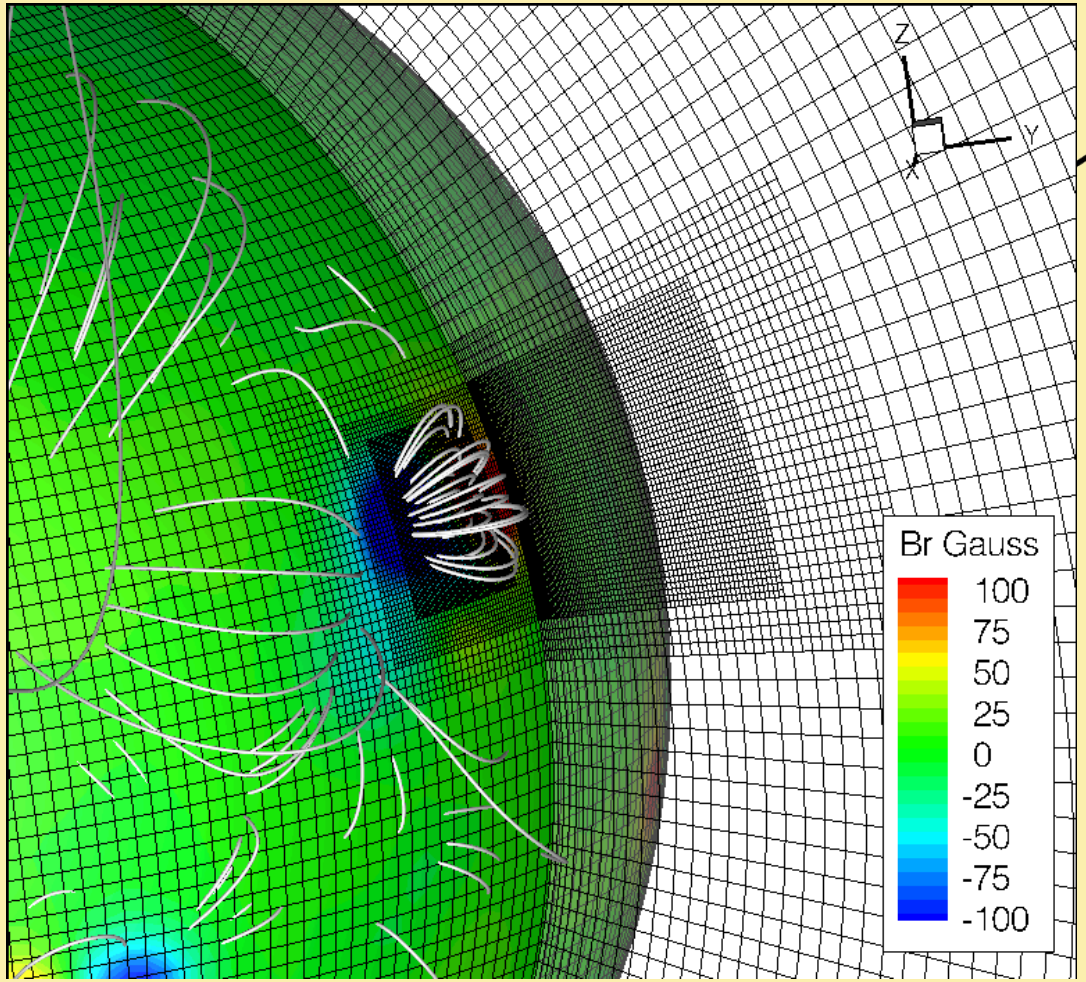
- Blue=MHD, Red=Potential





Coupling the Convection Zone to the Corona

- Send data from convection zone model (CZ) to solar coronal model (SC) at locations of the chromosphere layer, and outer boundary of CZ above the chromosphere. (repeat and reverse for two-way coupling)



Next generation of CZ model being developed is in spherical coordinates and will extend to a depth of 30 Mm and a height of 400 Mm

Summary

- **Gibson-Low Flux Rope CME Model**
  - Flux rope parameters specified by observations
  - Capable of reproducing observed features of CMEs in corona
  - Capable of reproducing in situ observations at 1AU: density, velocity and magnetic field
  - CME speed Magnetic Flux Relationship matches observations!
- **CME in the AWsoM Model Validated with SOHO, STEREO, SDO ACE and Wind Observations**
  - Present simulations model the May 13th 2005 event and March 7th 2011 CME events with realism
- **Modeling CME Initiation with Flux Emergence**
  - Current small-scale simulations produce high magnetic shear
  - Future large-scale simulations will be used initiate CMEs

Fitting Model Parameters

- Field strength and flux rope radius can be adjusted to produce the desired CME speed